

The 6th International Conference on Mining Science & Technology

New technology for coalbed methane power generation based on Stirling engine driven by porous burner

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Abstract

The development of coalbed methane (CBM) power generation is restricted by the gas source instability. The existing technologies such as steam turbine, gas turbine, and gas engine are not suitable for the instability. So a new technology of CBM power generation is put forward which is a Stirling engine system driven by porous burner. The Stirling engine is an external-combustion engine and its working fluid is not involved in combustion. Stirling engine works as long as heat supply is guaranteed, and therefore it is not conditioned by the gas source instability in itself. Porous burner is a premixed combustion technology in porous medium based on the excess enthalpy combustion. The porous medium is characteristic of the strong heat storage capability and the small combustion pore diameter, and accordingly it adapts well to the gas source instability. So the new CBM power generation technology, which combines the external-combustion distinction of Stirling engine and well adaptability to the gas source instability of porous burner, will agree with the coalbed gas source instability.

Keywords: stirling engine; coalbed methane (CBM); porous burner

1. Introduction

Coalbed methane (CBM) mainly consists of methane. It has been considered a major mine hazard and major greenhouse gas for a long time. Since the late 20th century CBM has received increased emphasis as a high-quality energy resource and valuable chemical material.

CBM resources are very abundant in China. According to the latest evaluation by the National Development and Reform Commission (NDRC) of China, CBM resources buried in the depth of 2000 m are about $36 \times 10^{12} \text{ m}^3$ [1].

Power generation is one of the most effective approaches for CBM utilization at present. It can realize the perfect combination of energy conservation, environmental protection, safety guarantee and economic benefits.

In the past few years, the Chinese government has made a number of policy frameworks and specific policies to promote the development of CBM power generation. These included: (1) “Suggested Opinions to Speed up Drainage and Utilization of CBM and CMM”, issued by the General Office of the State Council of China in June 2006; (2) “A Notice on the Management of CMM Prices”, published by the NDRC of China in 2007; (3) “A Notice of Implementation on CMM to Power Generation”, published by the NDRC in April 2007; (4) “A Notice on Subsidies to CMM Capture and Utilization”, published by the Ministry of Finance of China in April 2007 and (5) “Emission Standard of Coalbed Methane/Coal Mine Gas (on trial)”, published by the Environment Protection Agency of China and the National Quality Monitoring and Quarantine Agency of China in April 2008. Furthermore, the undergraduate specialty of coal and coalbed methane engineering were set up in China University of Mining and Technology and China University of Geosciences in 2008.

2. Gas source instability——bottleneck of CBM power generation

Although Chinese CBM power generation has kept fast development over the past 15 years, it still has many serious problems.

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The gas source instability is especially outstanding and has become a bottleneck which restricts the development of CBM power generation.

The gas source instability mainly reflects on three aspects: (1) Instability of gas concentration. On the one hand, the gas concentration is different with coal mine, extraction method, drainage technology and extraction phase. On another hand, driven by the policy: “Coalmine Methane Drainage First and Coal Mining Second”, concentration of drainage gas is less than 25% and of ventilation air methane is normally below 2% in China. So, traditional combustion technologies become less and less powerful especially for low concentration gas. (2) Instability of gas production. The gas production capacity has great difference with coal mine and drainage phase. Therefore, the single unit capacity range of CBM power generator must be wide. (3) Mobility of gas recovery location. When a regional gas source is exhausted, the gas recovery location will change correspondingly. Otherwise, the gas long-distance transmission pipeline will be needed. Thus, CBM generating set must be easy to move.

The existing technologies such as steam turbine, gas turbine and gas engine, are not suitable for the instability (Table 1).

Table 1. Comparison of existing CBM power generation technologies

Generation technology	Performance				
	Adaptation of combustion technique to instable gas source	Single unit capacity (kW)	Easy to move	Generating efficiency (%)	Pollutant level
Steam turbine	good	>30 000	No	11~16	
Gas turbine	satisfactory	10~10 000	Yes	24	High
Gas engine	poor	50~5 000	Yes	40	High

3. A new technology of CBM power generation—stirling engine system driven by porous burner

The development of CBM power generation is restricted by the gas source instability. The existing technologies are unable to satisfy the instability. So a new technology of CBM power generation is put forward which is a Stirling engine system driven by porous burner.

3.1. Adaptability of Stirling engine to gas source instability

The principle of Stirling engine has been known for a long time[2–3]. The distinction of this engine is the transfer of working medium between two cylinders without leaving the engine (Fig. 1). Heat energy, which is converted to motion energy available at the crank, is supplied from an external source via a heat exchanger or heater. Firstly, Stirling engine is an external combustion engine. This engine itself isn't limited by the gas source instability provided that the heat supply is stable. Secondly, this engine power varies from 1 kW to 10 000kW which can satisfy different gas production. Thirdly, this engine is easy to move. Its components can be reduced by 40% than gas engine and it is small in volume. Finally, the power generating efficiency of Stirling engine is highest in theory and has been comparable to gas engine presently.

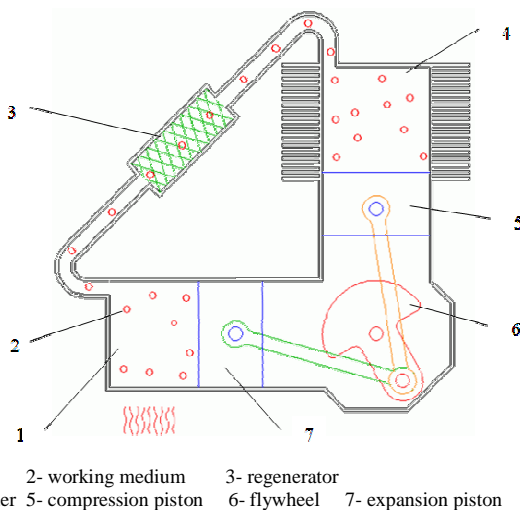
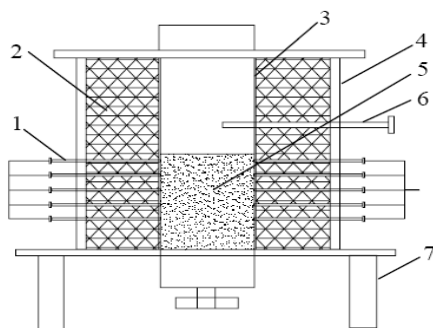


Fig. 1. Principle of Stirling engine

3.2. Adjustability of porous burner to gas source instability

Analysis indicates that Stirling engine is capable of suiting the gas source instability as long as heat supply is guaranteed. Now the combustion technology has become a key problem which can adapt to the gas source instability, especially to low concentration gas. Porous burner is undoubtedly the first selection. Firstly, it is a premixed combustion technology in porous medium based on the excess enthalpy combustion (Fig. 2). The porous medium is characteristic of the strong heat storage capability and the small combustion pore diameter [4–6]. Therefore, this burner adapts well to the gas source instability, and can broaden the lean flammability of coal mine gas so as to fire the low concentration gas which cannot be fired in free chamber [7]. Secondly, the pollutants emission is lower than conventional premixed or diffusion combustion. Combustion pores are uniformly distributed and heat exchange coefficient is very large in porous medium, thus temperature is uniformly distributed in combustion chamber. Finally, its thermal efficiency is high and can save fuel by 30%~50% than Bunsen burner at the same heat load.



1-thermocouple sensor 2-heat insulation layer 3-inner liner
4- outer cylinder 5- porous medium 6- igniter 7- support base

Fig. 2. Structure of porous burner

3.3. CBM power generation system based on Stirling engine driven by porous burner

In order to break the bottleneck of CBM power generation, a new method of CBM power generation is proposed based on Stirling engine system driven by porous burner.

Stirling engine is an external-combustion engine and not conditioned by the gas source instability in itself. Porous burner is an excess enthalpy combustion technology in porous medium and adapts well to the gas source instability.

So through combining the external-combustion distinction of Stirling engine and well adaptability to the gas source instability of porous burner, the new technology will agree with the CBM gas source instability (Fig. 3).

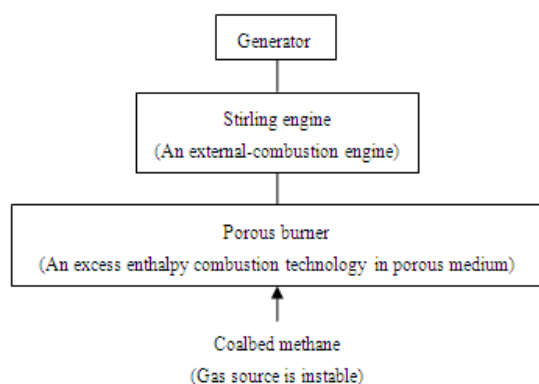


Fig. 3. CBM power generation system based on Stirling engine driven by porous burner

4. Conclusions

(1) The development of coalbed methane (CBM) power generation is restricted by the gas source instability. The existing technologies such as steam turbine, gas turbine and gas engine, have been incapable of suiting the instability.

(2) A new technology of CBM power generation is put forward which is a Stirling engine system driven by porous burner. This technology combines the external-combustion distinction of Stirling engine and well adaptability to the gas source instability of porous burner, and will agree with the CBM gas source instability.

Acknowledgements

Financial support for this work, provided by the Specialized Research Fund for the Doctoral Program of Higher Education of China and the Science Foundation for Youth Scholars of China University of Mining & Technology, is gratefully acknowledged.

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